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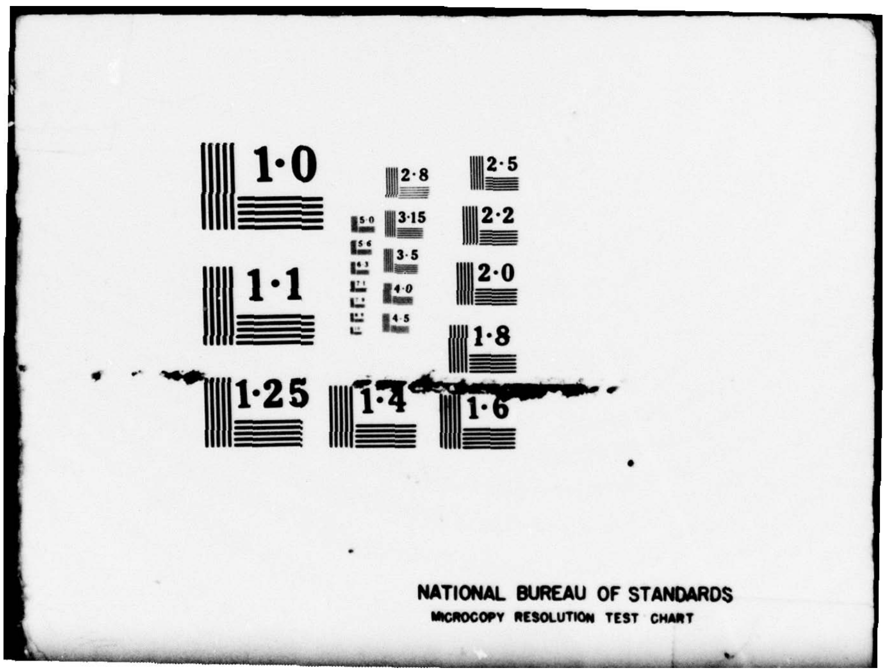
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DESIGN AND DEVELOPMENT OF THE 81 MM MORTAR CARTRIDGE SIGNAL, UNDERWATER SOUND (MCSUS), XN-1

MARCH 1978

NWS

NAVAL WEAPONS STATION, YORKTOWN, VIRGINIA 23691

by
Robert M. Johnson

Naval Explosives Development Engineering Department

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20. ABSTRACT.

This report describes a mortar fired, underwater ordnance item, the 81 mm Mortar Cartridge Signal, Underwater Sound (MCSUS), XN-1. The signal consists of a hydroadiabatic fuze adapted to an inert loaded, 81 mm Mortar Cartridge, M374. This fuze has no moving parts and incorporates a new type of firing train that does not contain primary explosive.

The signal is propelled from a ship-mounted Mortar, Mk 2 Mod 0, to enter the water at selectable horizontal ranges up to 4932 yards (4500 meters). It then rapidly descends to a depth of 1000 feet (305 meters) and detonates a 1-ounce (28-gram) explosive charge. The acoustic output is used to measure deviations from linearity of long, ship-towed hydrophone arrays.

F O R E W O R D

1. This is a report documenting the design and development of the 81 mm Mortar Cartridge Signal, Underwater Sound (MCSUS), XN-1.

2. The effort reported herein was authorized and funded as part of the Naval Underwater Systems Center, Newport, Rhode Island Work Request No. N6660477WR75093 of 7 April 1977.

Released by

W. McBride

W. McBRIDE, Director
Naval Explosives Development
Engineering Department
March 1978

Under authority of
LEO A. HIBSON, JR.
Commanding Officer

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This activity wishes to express appreciation to Ms. Kay Kasher of the U.S. Army Armament Materiel Readiness Command, Rock Island, Illinois for superb cooperation in arranging and expediting delivery of mortar cartridge components and associated material.

CONTENTS

DESIGN AND DEVELOPMENT OF THE 81 MM MORTAR CARTRIDGE SIGNAL, UNDERWATER SOUND (MCSUS), XN-1

I. GENERAL

The 81 mm Mortar Cartridge Signal, Underwater Sound (MCSUS), XN-1, hereafter referred to as the signal, was designed and developed by the Naval Explosives Development Engineering Department (NEDED), Naval Weapons Station (NAVWPNSTA), Yorktown, Virginia to support the Navy Long Range Acoustic Propagation Project (LRAPP). It is used to measure changes in shape of long, linear, ship-towed hydrophone arrays by providing a source of underwater acoustic energy at a distance of an array length or more broadside to the array. The signal is projected the desired distance by a ship-mounted Mortar, Mk 2 Mod 0. The application and use of this signal are described in detail in a technical memorandum[1] from the New London Laboratory, Naval Underwater Systems Center (NLONLAB NUSC), New London, Connecticut.

The hydroadiabatic fuze recently developed for the Signal, Underwater Sound (SUS), Mk 123 Mod 0,[2] was adapted for the signal because it can withstand the acceleration forces and pressures encountered during mortar firing. This device meets all of the requirements for fuzes (or arming and firing mechanisms), but contains no moving parts. Secondary explosive is initiated directly by adiabatic compression of air, which can only occur when the fuze is subjected to high hydrostatic pressure. Since primary explosive is not used in the explosive train, an out-of-line arming mechanism is not required. The simplicity, safety, reliability and ruggedness of the hydroadiabatic fuze make it ideally suited to this application.

There may be other applications for a gun-fired SUS with different requirements for detonation depth, explosive charge weight or horizontal range. By changing the shear disc assembly, the hydroadiabatic fuze configuration described herein can detonate a charge at preset depths between 1,000 and 10,000 feet. Another configuration is used for depths between 10,000 and 18,000 feet. The explosive charge

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[1]Martin, Robert L., Koenigs, Paul D., NLONLAB NUSC Tech Memo No. 771259, *Application of an 81 mm Mortar to Measure Changes in Shape of Long Linear Arrays at Sea*, 17 Dec 1977.

[2]McGann, E. Yancey, Johnson, Robert M., NWSY TR 76-3, *Design and Development of the Signal, Underwater Sound, Mk 123 Mod 0*, Dec 1976.

weight in the signal can be increased to 2.1 pounds. Greater range and charge weight could be obtained by adapting the unique capabilities of the hydroadiabatic fuze to projectiles that are used with other guns.

II. DESCRIPTION

Figure 1 shows external and sectioned views of the signal. Figure 2 is a general arrangement of the Hydroadiabatic Fuze, EX-2. The overall dimensions of the signal are 3.18 inches (81 mm) in diameter by 20 inches (508 mm) long, and the total weight is 9.5 pounds (4.3 kilograms).

The signal, Figure 1, is similar to the Cartridge, 81 mm:HE, M374, with the following exceptions:

- The Hydroadiabatic Fuze, EX-2, is used instead of the standard impact or proximity type fuzes.
- The booster cavity in the projectile contains 1 ounce (28 grams) of flexible explosive, MIL-E-46676.
- The projectile is loaded with an inert filler instead of Composition B explosive.
- The signal is painted blue with a yellow band and white markings to indicate that it is classified as a practice round containing a small amount of high explosive.

The rear of the bourrelet section of the projectile is fitted with a polyvinyl chloride obturator ring in a circumferential groove. Aluminum fin assembly M149, consisting of an ignition cartridge housing and six extruded fins, is assembled to the rear of the cartridge. The ignition cartridge housing is essentially a perforated cylinder threaded at the forward end for assembly to the projectile. The housing contains the ignition cartridge and a pressure plate seated on a recessed shoulder just above the ignition cartridge. The perforations in the housing provide for transmission of the flash from the ignition cartridge to the propellant increments. Steel increment holders with kidney-shaped projections hold the propellant increments in place around the exterior of the ignition cartridge housing. The fins, attached to the rear of the housing, consist of six extruded blades canted counterclockwise 5 degrees at the rear to introduce spin during air flight and underwater descent. A percussion primer is located in the hub of the fin assembly which contains a central flash hole for transmission of the flash from the primer to the ignition cartridge. Propelling charge M90 used with this cartridge consists of nine increments of M9 flake propellant. Increment A contains 184 grains while the eight other increments (B)

contain 168 grains each. Each increment is contained in a water-repellant cotton cloth bag having a buttonhole at each end. The bags are attached to the cartridge by engaging the buttonholes over the kidney-shaped projections of the increment holder. Increment A is assembled spirally underneath the eight increments.

The Hydroadiabatic Fuze, EX-2 (Figure 2), hereafter referred to as the fuze, includes a body which is loaded with a column of CH-6 explosive. The loaded body contains a conical cavity which extends for a short length into the CH-6 column. The shear disc assembly, Figure 3, includes a thin gold shear disc; a shear washer with a calibrated, sharp edged hole; a phenolic washer; and a soft copper ferrule. The ferrule is crimped to contain the other parts of this assembly. Referring to Figure 2, the cap is screwed onto the body and torqued to compress the washer and shear disc assembly, forming metal-to-metal seals between the shear disc, shear washer, ferrule and body. The booster housing, containing the Composition A-4 explosive booster, is screwed onto the other end of the body and torqued to compress the spacer and disc against the body. A hole in the spacer provides an air gap between the disc and booster. The O-ring is included to seal the booster end of the assembly. The nose adapter is screwed onto the booster housing and torqued, completing the fuze assembly. The nose adapter protects the shear disc from the dynamic forces at water impact, and the two cross holes permit free flow of water required to initiate the fuze after rupture of the shear disc. The fuze was designed so that the shape and weight would not materially change the known ballistic characteristics of the standard round.

III. OPERATION

The signal is fired from the Mortar, Mk 2 Mod 0, using the procedures for the M374 Cartridge, except there are no fuze safety wires to be removed. After the signal enters the water, it decelerates to sink at an approximate terminal velocity of 28 feet per second. When the signal reaches a depth of 1000 plus or minus 100 feet, hydrostatic pressure punches a hole through the shear disc assembly in the fuze. The inrushing water acts as a piston to adiabatically compress the air in the conical cavity which terminates in the highly confined CH-6 column. The rapid temperature rise of the air initiates a burning reaction in the explosive column. If this column was very long, the reaction would transform to a detonation. Based on previous work,[3] the inclusion of a metal disc plus an air gap is used to minimize the length of the explosive train. When the burning reaction reaches the disc, it ruptures and fragments. The pressure ratio across the

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[3]Cooper, P. W., Armour Research Foundation of Illinois Institute of Technology, *Final Report ARF Project D178, Ord Project No. TN2-8109 Contract No. DA-11-022-501-ORD-2892.*

bursting disc constitutes a shock wave. The shock wave and hot disc fragments speed across the air gap and initiate high order detonation of the booster. The booster then initiates the 1-ounce flexible explosive which ruptures the cartridge body and produces a broadened acoustic signal.

IV. HISTORY OF TESTS AND OPERATIONAL USE

The hydroadiabatic fuze adapted to the signal had been subjected to considerable safety and reliability testing as reported in NWSY TR 76-3.[2] It had not, however, been subjected to gun firing or water entry forces to be encountered in this application. Also, the amount of explosive to provide an adequate acoustic output had not been determined.

The time from the original discussions of the signal requirements to the two required delivery dates was less than 3 months. This did not permit much time for design; development; obtaining mortar cartridge parts; fabricating fuze parts; load, assemble and pack operations; and shipment to the west coast. As a result, only a limited development program could be conducted before deliveries were made, and the at-sea operations reported by NLONLAB NUSC[1] provided information that would normally be obtained during development tests.

Initially, the mortar cartridge components were requested from the U.S. Army Armament Materiel Readiness Command, Rock Island, Illinois. Then, preliminary tests were conducted at the NAVWPNSTA Yorktown blasting pit. Hydroadiabatic fuzes were hydrostatically initiated in a pressure pot to determine design parameters for the protective nose adapter. Minor modifications were made to existing fuze parts, the nose adapters were fabricated and the fuzes were loaded. When the mortar cartridge components were received, assembly and packing of 84 signals was initiated to meet the delivery dates. It had been agreed from the outset that the 3-gram Composition A-4 booster, that could be accomodated in the existing fuze hardware, should provide an adequate acoustic output for the intended purpose. The 84 signals were assembled, therefore, as described in Section II, but without the 1-ounce flexible explosive charge.

It was felt necessary to conduct function tests of the signal prior to at-sea operations, however, a Mk 2 Mod 0 Mortar was not available. To determine whether the signal would function after being subjected to high water entry velocities, it was decided to simulate the last half of the air trajectory by launching units into deep water from an aircraft. Six signals, without the propellant charges, were tested

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[2] *Op cit.*
[1] *Op cit.*

in this manner off Key West, Florida. The detonations were monitored by sonobuoy transmissions which were received and recorded aboard a surface vessel. Five of the six signals detonated, however, the acoustic output was severely muffled by the heavy cartridge body, and it was not known whether this sound level would be above the self noise of the towed array.

During the first exercise at sea, six signals were used and it was determined that they detonated, but could not be clearly heard at the array. Since the remaining signals were already enroute to San Diego, California for the second exercise, it was decided to try a simple fix that could be accomplished aboard ship. This involved drilling four 1/4-inch diameter holes through the projectile, permitting free flooding around the booster housing to provide better coupling of the detonation to the water. Pressure pot tests indicated that this change increased the acoustic output.

During the second exercise, 14 undrilled and 15 drilled signals were used. The undrilled units were dropped over the side, 13 providing a weak direct arrival and the output of one was not observed. Eleven of the drilled signals were dropped over the side with eight providing sharp direct and surface arrivals but weak bottom returns, and three were not heard due to array noise. The other four drilled units were mortar fired and all provided a sharp direct arrival.

It was concluded from the NLONLAB NUSC exercises[1] that the mortar fired signal is an excellent approach for measuring deviations from linearity of long, ship towed hydrophone arrays. NLONLAB NUSC recommended that the amount of explosive be increased sufficiently to rupture the cartridge body of signals used for this purpose in the future.

When the Naval Ocean Research and Development Activity (NORDA), NSTL Station, Mississippi requested signals for the same application, pressure pot tests were conducted to determine the additional explosive required. It was found that 1 ounce of flexible explosive, MIL-E-46676, successfully ruptured the cartridge body. Flexible explosive was used because it is nonhygroscopic and will detonate in the unsealed cartridge booster well. Due to financial limitations only three of this type of signal, as described in Section II, were provided. NORDA reported that all three operated properly and provided the desired measurement information.

[1] *Op cit.*

V. SUMMARY

Summarizing the signal operating results of the at-sea exercises, 30 were judged to have functioned and 4 were not observed by the hydrophone array. The unobserved units were part of the group that did not contain the 1-ounce flexible explosive charge. Under conditions of high array self noise, the low output of these signals would not have been observed. The development of this signal provides a new way to introudce an explosive-acoustic source into the ocean. Although no wide usage is envisioned, it can fill a need for certain operational requirements. Larger explosive charges can easily be installed to increase the versatility of this signal.

VI. REFERENCES

1 Martin, Robert L., Koenigs, Paul D., NLONLAB NUSC Tech Memo No. 771259, *Application of an 81 mm Mortar to Measure Changes in Shape of Long Linear Arrays at Sea,* 17 Dec 1977.

2 McGann, E. Yancey, Johnson, Robert M., NWSY TR 76-3, *Design and Development of the Signal, Underwater Sound, Mk 123 Mod 0,* Dec 1976.

3 Cooper, P. W., Armour Research Foundation of Illinois Institute of Technology, *Final Report ARF Project D178, Ord Project No. TN2-8109 Contract No. DA-11-022-501-ORD-2892.*

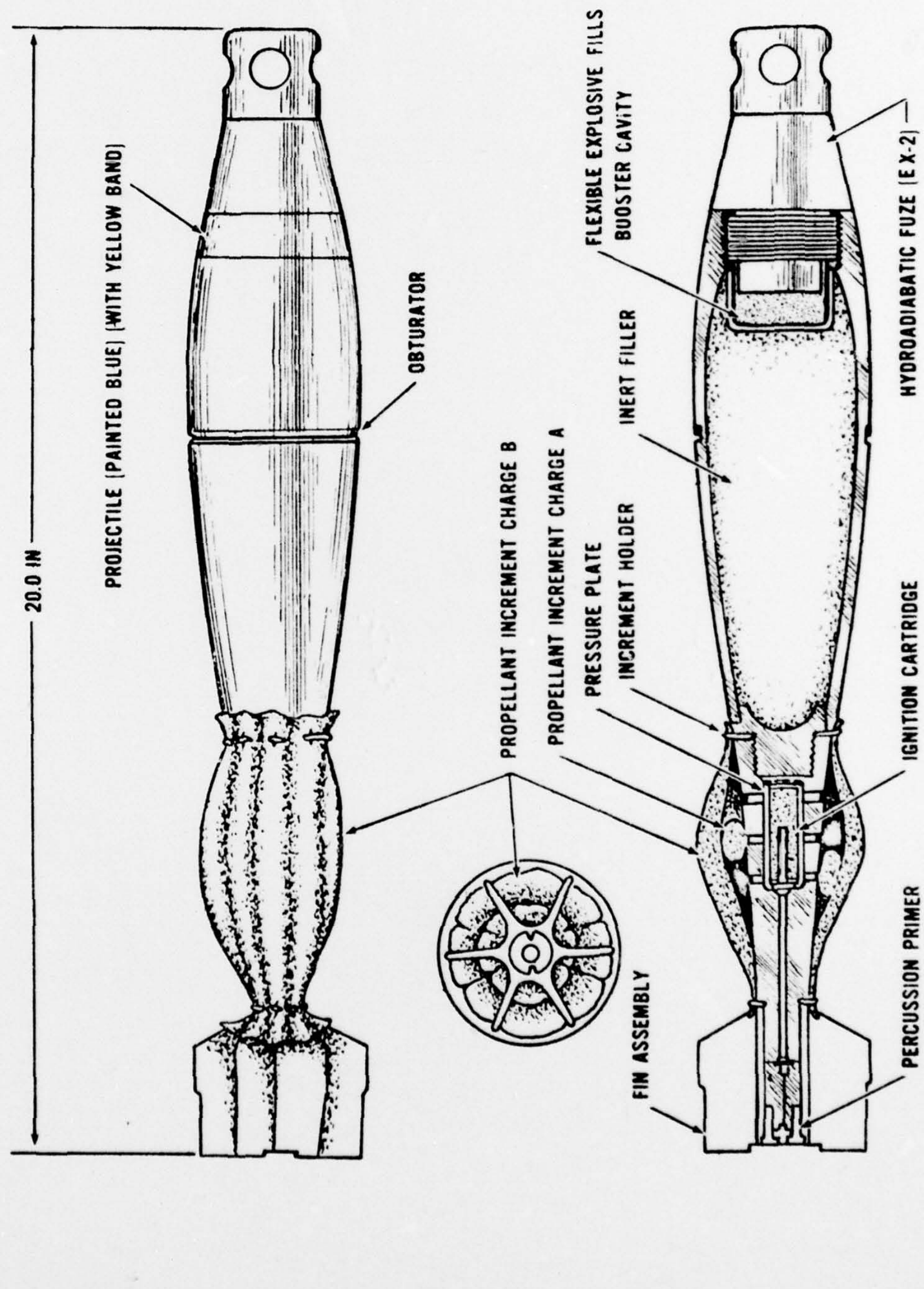


FIGURE 1. 81MM MORTAR CARTRIDGE SIGNAL, UNDERWATER SOUND (MCSUS), XN-1

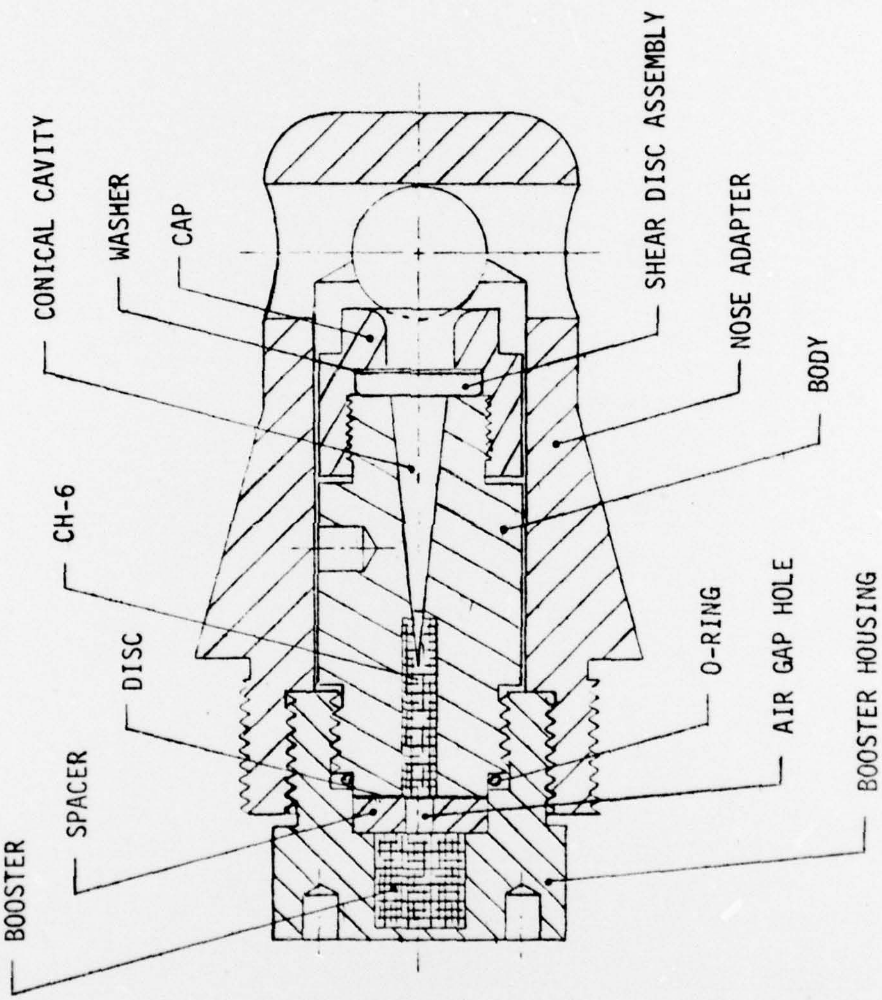
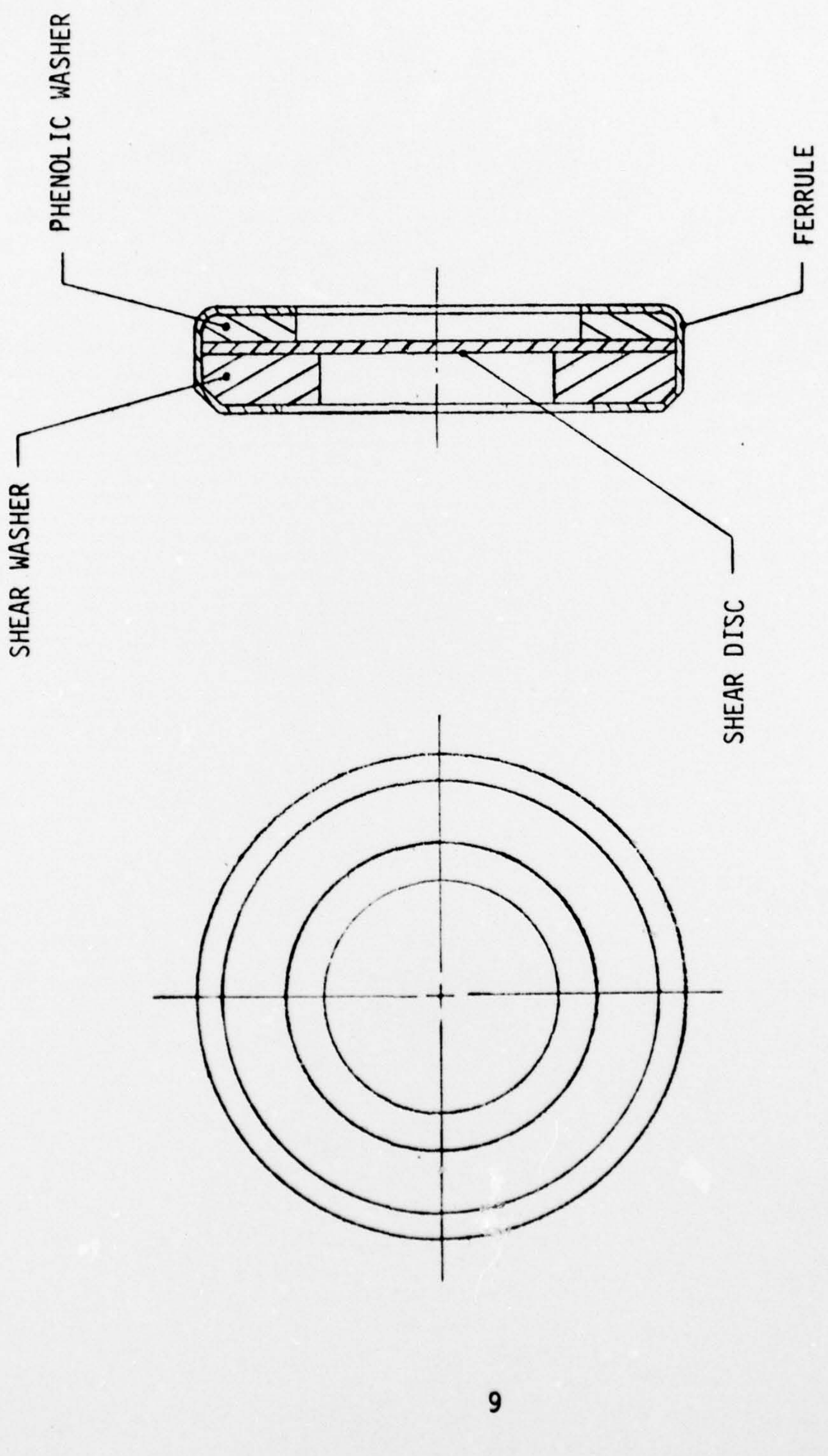


FIGURE 2. HYDROADIABATIC FUZE, EX-2



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